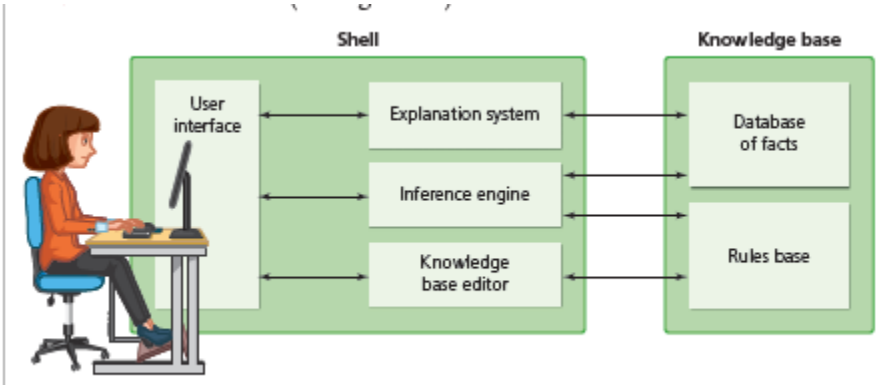
7 Expert Systems

- Expert systems are computer based systems used to solve problems such as providing a diagnosis of something
- They make use of the knowledge of a number of human experts within a specific field to help create a knowledge base
- They use reasoning to produce possible solutions
- Data referred to as database of facts is stored within the computer and represents the knowledge part of a knowledge base
- The system uses a set of rules which represents the reasoning



▲ Figure 7.1 A graphic representation of our expert system

7.1 Components of expert systems

- The shell consists of the explanation system, inference engine, knowledge base editor and user interface
- The knowledge base consists of database of facts and rules base

User Interface

- User interface is how the computer interacts with the user and the user with the expert system
- It displays questions, opinions, results and information on a screen

- It enables the user to type in answers to the questions and data
- It usually consists of a keyboard and mouse together with a monitor
- Validation checks are carried out to ensure the minimum number of invalid responses are entered by the user

Inference Engine

- It performs the reasoning of an expert system
- It uses a series of IF…THEN statements within the rules base and interrogates the database of facts in the knowledge base
- It uses inputs from the user to try and match them with the contents of the database of facts
- It processes the rules to try and reach possible solutions
- Can also generate questions via the user interface based on the inputs it has received so that is can use the answers to narrow down the number of possible solutions
- The method used by inference engine involves the use of forward chaining, backward chaining or a combination of both

Knowledge Base (as a database of facts and rules base)

- The knowledge base consists of database of facts and rules base
- The database of facts is built up by the engineer on information and knowledge of the subject specialists (experts), it may also be built up from existing databases for the topic
- Rules base is a set of rules which are usually in the form IF…THEN

Explanation System

- It explains the logical reasoning that the expert system has used to come to its conclusions to the user
- It also explains why a specific fact was needed or not and justify its recommendation for the reasoning

Knowledge Base Editor

- It is a software that allows the knowledge engineer to edit the rules and facts within the knowledge base to bring them up to date

Explain the role of the knowledge engineer:

- The knowledge engineer is responsible for maintaining the system
- The knowledge engineer edits and adds the facts in the knowledge base
- The knowledge engineer edits and adds the rules in the rules base part if the knowledge base
- The knowledge engineer deletes unused rules from the rules base

Describe how the knowledge base is used to interact with the other components when an expert system is used to solve a problem:

- Knowledge base consists of a database of facts and a rules base
- Inference engine uses the rules base to reason through the symptoms
- Inference engine uses the data or facts in the knowledge base to reason through the symptoms
- Inference engine compares the symptoms to those in the knowledge base
- Inference engine uses the rules base of IF…THEN rules
- Knowledge base editor enable the knowledge engineer to edit rules and facts within the knowledge base

7.2 Different scenarios where expert systems are used

Mineral Prospecting

- Expert systems are used to help in making decision on where to drill for a specific mineral
- The geologist enters data about the types of rocks and geological structure as well as the minerals to be found at the site under consideration
- The expert systems knowledge base will store models of successful drilling sites and their associated minerals together with a rule base

- The inference engine then compares this data with the models in the knowledge base using the IF…THEN rules in the rules base
- The system may ask the geologist further questions through the user interface
- The resulting percentage probabilities of finding the mineral at this site are produced
- It will as well as produce a conclusion about the existence of a particular ore deposit, providing explanation regarding their conclusion

Investment Analysis

- The user interface will ask questions about the investor to the financial investor such as the amount the client wishes to invest, level of risk investor is willing to take, desired rate of return, duration the investor is willing to make the investment for.
- Depending on the answers to the questions, the system may ask further questions through the user interface
- The database of facts will consist of all the information the bank has gathered over the years about the performance and stability of different companies
- The rules in the rules base will be created by an expert investor
- The expert system will allow the financial advisor to add rules to the rules base as they see fit based on their experience dealing with the investor
- The inferences engine will then produce recommendations for purchasing stocks or share in a company together with the reasons for recommending these particular stocks and share.
- The financial advisor will make the final decision based on the expert system's recommendation

Financial Planning

- Expert systems involve the client completing a detailed questionnaire regarding their personal and economic situation, including income, taxes paid or due, investments, employee benefits, marital status, number of dependents as well as any obligations such as retirement plans or children's university education
- The results of the questionnaire are entered using the user interface.
- The inference engine analyses this information using the database of facts and a very large number of rules in the system

- The database uses the results of books and articles which have been published to personal financial planning as well as information gathered from interviews with experts like professional financial advisors
- A report would then be produced by the financial advisor as to the clients recommended financial plans
- The repot would be based on a combination of a human expert's insights and the use of the results of the expert system
- The report would serve as financial action checklist for the client in order to achieve their financial plans

Insurance Planning

- Details of the individual would be entered into the user interface such as the applicant's age, gender, whether they smoke and general health
- The user interface will ask questions of user to the consultant
- The inference engine will compare the responses with the facts in the knowledge base using the IF…THEN rules
- The inference engine will produce a recommendation for how much the applicant will pay each month for their policy or recommend whether the application is rejected
- It may inform them of the details of the policy
- The recommendation is output through the user interface
- The consultant will use the expert system's recommendation to make a final decision

Car Engine Fault Diagnosis

- questions regarding the problems with car are asked and the mechanic types in the symptoms using the user interface
- the expert system would supply a list of possible causes of the problem and the mechanic would decide which of the suggestions are most likely
- the expert systems inform the mechanic of a range of readings from sensors
- these readings are also used by an inference engine after comparison with those in the knowledge base to produce a list of possible faults
- the mechanic makes the final decision based on the expert systems conclusions

Medical Diagnosis

- the creation of a medical diagnosis expert system starts with the production of the shell followed by the knowledge base
- the knowledge base is created by the knowledge engineer who interviews a number of expert doctors and then shapes the knowledge into a form that can be easily accessed by the system
- the components of an expert system are used to produce a list of possible diagnoses
- the user interface allows the patient or doctor to enter symptoms and at the end of the process, displays the output
- the knowledge base provides the database of existing illnesses as well as the rules from the rules base often IF…THEN rules
- the IF part is the symptoms part and the THEN part is the illness or disease that is suggested
- the inference engine searches the knowledge base for similar symptoms to those entered by comparing those typed in with those in the knowledge base
- this is the reasoning part of the system
- the knowledge base editor allows for the knowledge base to be increased by adding further rules and data
- the explanation system clarifies how the expert has produced its possible diagnoses

Route Scheduling for Delivery Vehicles

- An expert system would store the locations of each distribution point, the type of vehicle being used and the working hours
- The scheduler would type in the destinations and quantity of the parcels for the day
- The expert system would match those against the locations and the available types of vehicles
- The expert system would suggest how many drivers would be needed and the kind of vehicle for each driver
- The expert system suggest the allocation of orders to each vehicle and suggest a list of goods in reverse order so that each vehicle had the first order loaded on to the vehicle last
- The system would take account of the fuel, time, traffic and road conditions then output the most efficient route

Plant and Animal Identification

- The inference would use a series of IF…THEN rules
- Plants are divided into woody or herbaceous
- If they are woody, the system through the user interface could ask another question such as whether they have a single trunk which would lead in turn to other questions based on the shape/type of leaf and so on
- The possibilities would be output through the user interface
- The database of facts, which would be interrogated by the inference engine would include the data regarding all knowledge about as many species as possible
- This type of system would ask questions rather than inviting the expert to type in details about the plant
- Animal classification or identification follows a similar pattern

7.3 Chaining

- When an inference engine interrogates the knowledge base, it imitates the way human would use reasoning
- It uses what is known as chaining
- The reasoning that the inference engine uses consists of backward or forward chaining or a combination of both

Backward Chaining

- Backward chaining starts with a list of goals or hypothesis and tries to find support for their hypothesis
- It works backwards from the goal
- An inference engine would search the inference rules until it find on which has a THEN part that matches the goal or hypothesis
- If the IF part of that rule is known to be true, then it is added to the list of goals
- Because the list of goals determines which rules are selected used, this method is called as **goal-driven**

Example 7.1 Backward chaining

Suppose a zoo has just received a new animal from Africa. We shall call her Edwina and she has been delivered in an enclosed trailer. We cannot see inside the trailer, but we are given two facts about Edwina:

Fact 1: Edwina has hooves.

Fact 2: Edwina can run fast.

We want to know whether Edwina has a striped coat. In terms of using an expert system, the goal is to decide whether Edwina has a striped coat. We will use a rules base containing the following four rules:

Rule 1: IF X has hooves and can run fast, THEN X is a zebra.

Rule 2: IF X cannot fly and X is a bird, THEN X is an ostrich.

Rule 3: IF X is a zebra, THEN X has a striped coat.

Rule 4: IF X is a giraffe, THEN X has irregular shaped spots.

We call the part that begins with IF the premise (what we are supposing could be true). We will call the part that is based on the result of whether the premise is true, the THEN part, the conclusion.

Using backward chaining, an inference engine can decide whether Edwina has stripes in four steps. The goal that has to be proved is 'Edwina has a striped coat'.

Step 1: 'Edwina' replaces X in Rule 3 to see if its conclusion matches the goal, so Rule 3 becomes:

IF Edwina is a zebra, THEN Edwina has a striped coat.

Since the conclusion matches our goal 'Edwina has a striped coat', we now need to see if the premise – Edwina is a zebra – can be proved. So, the premise now becomes our new goal: 'Edwina is a zebra'.

Step 2: Again, replacing X with 'Edwina', in Rule 1, the rule becomes:

IF Edwina has hooves and can run fast, THEN Edwina is a zebra.

Since the conclusion matches the current goal 'Edwina is a zebra', the inference engine now needs to see if the premise – Edwina has hooves and can run fast – can be proved. The premise therefore becomes the new goal: 'Edwina has hooves **AND** can run fast'.

Step 3: Since this goal is a combination of two statements, the inference engine breaks it down into two sub-goals, both of which must be proved: 'Edwina has hooves' and 'Edwina can run fast'.

Step 4: To prove both of these sub-goals, the inference engine sees that both of these sub-goals were given as Fact 1 and Fact 2 at the start of this problem.

Therefore, the statement is true: 'Edwina has hooves AND can run fast'.

The premise of Rule 1 is true and the conclusion must be true: Edwina is a zebra.

It follows that the premise of Rule 3 is true and the conclusion must be true: Edwina has a striped coat.

Notice that Rules 2 and 4 were not used.

Forward Chaining

- Forward chaining starts with the available the data and uses inference rules to extract more data until a goal is reached
- An inference engine using forward chaining searches the inference rules until it finds on where the IF statement is known to be true
- When such a rule is found, the inference engine uses the 'THEN' part to cause the addition of new facts
- The inference engine will repeat this process until a goal is reached
- The data entered determines which rules are selected and used and so this method is called **data-driven**

Example 7.2 Forward chaining

Suppose that the goal is to decide the pattern of the coat of Edwina. Again, we can assume that Edwina has hooves and can run fast and that the rules base contains the following four rules:

Rule 1: IF X has hooves and can run fast, THEN X is a zebra.

Rule 2: IF X cannot fly and X is a bird, THEN X is an ostrich.

Rule 3: IF X is a zebra, THEN X has a striped coat.

Rule 4: IF X is a giraffe, THEN X has irregular shaped spots.

Again, we have two known facts:

Fact 1: Edwina has hooves.

Fact 2: Edwina can run fast.

With forward chaining, the inference engine can deduce that Edwina has a striped coat by using the following steps:

Step 1: Since the facts we are given show that Edwina has hooves and Edwina can run fast, the premise of Rule 1 is matched by replacing X with 'Edwina' (IF Edwina has hooves and can run fast). The inference engine comes to the conclusion: Edwina is a zebra.

Step 2: We can now use Rule 3 by replacing X with 'Edwina' (IF Edwina is a zebra). The inference engine comes to the conclusion: Edwina has a striped coat.

Compare the Use of Forward and Backward Chaining [6 marks]:

- Both are method used by an inference engine
- Both use a rule base to attempt to solve problems
- Both involve the output of one rule activating another rule
- Forward chaining is bottom up reasoning/backward chaining is top-down reasoning
- Forward chaining starts with a set of known facts and applies rules to generate new facts

- Forward chaining continues until it reaches a predetermined goal
- Forward chaining checks the facts against a predetermined goal
- Forward chaining is data driven rather than goal driven
- With forward changing data determines which rules are used in a rules base
- With backward chaining goals determine which rules are used in a rules base
- Backward chaining starts with a goal or hypothesis and looks for rules to support the hypothesis
- Backward chaining can either support or reject an hypothesis

7.4 Applications of forward and backward chaining

- Forward chaining are commonly use to solve more open ended problems of a design or planning nature such as establishing the configuration of a computer system
- Backward chaining is used if there are very few possible goals or conclusions and well defined

Diagnoses

- A rule base is a set of rules which an inference engine uses
- The inference engine finds possible diagnoses by using a form of reasoning
- The inference engine uses the data or facts in the knowledge base to reason through the symptoms
- The reasoning involves forward chaining, backward chaining or a combination of both
- User interface asks questions about the illness and the answer and data would be entered by the doctor or patient
- Inference engine compares symptoms to those in the knowledge base
- Inference engine uses the rules base of IF…THEN rules/comparison
- Knowledge base editor enables the knowledge engineer to edit rules and ad facts within the knowledge base
- Description of forward chaining: (*Searches through inference rules to find one where the IF statement is known to be true. If answer not found, further questions are asked. When such a rule is found, the inference engine uses the 'THEN' part to find the illness)*
- Description of backward chaining
- The system produces a probabilities of diagnoses/possible diagnosis

- Explanation system produces reasons for suggestions which are output using the user interface
- The doctor chooses the most appropriate diagnosis and use it or reject all

Gaming

NPC Games (forward chaining)

- When setting up the system the knowledge engineer would have gathered from the game expert known facts such as individual weapon characteristics and their range as well as which weapon is best for achieving the goal of eliminating the target
- The input variable may be the distance to the target, the type of weapon and the range of the weapon
- The system will need to output the type of weapon, why it was chosen as well as the characteristics of the weapon
- As the contents of the frame are constantly chaining, the NPC will constantly have to re-evaluate the situation much like a human player
- Creation of an expert system will improve game play and provide a challenge with the NPC making its own decision of weapon selection
- The inference engine uses forward chaining
- This method uses the data or facts which are input to the system and uses rules to determine a goal
- Using the forward chaining method, a series of IF statements are executed that sort through the data to THEN find a goal
- The goal in this case is an appropriate weapon
- These IF questions could be based on whether the target is a missile of some sort or another player
- The THEN part will be the recommended type of weapon

Chess (backward chaining)

- In chess there are a fixed number of moves to reach a winning position
- To computer all the possible ways of reaching a winning position, the system chains backwards and builds up a list of possible ways together to the winning position
- Backward chaining involves using all the possible premises which lead to getting a ‘checkmate’ conclusion

- Backward chaining is used in gaming that have fewer rules

Artificial Intelligence

- Artificial intelligence (AI) can be thought of as a piece of software that simulates or mimics the behavior and judgment of a human being.
- It involves the system being able to learn reason and assess its own actions.
- In AI, forward chaining can be used to solve logic problems using rules and previous learning to find solutions to problems.
- An AI might use forward chaining to look at the available information, answer a question or solve a problem.
- Forward chaining works through the logic of a problem from beginning to end.

There are countless applications of AI: in the healthcare industry for dosing drugs (calculating the dose of drugs to be given to a patient) and suggesting different treatment for patients; in surgical procedures in operating theatres in hospitals; in computers that play chess and in self-driving cars. Each of these machines must be able to consider each action it takes, as each action will have an impact on the end result. In chess, its goal is to get its opponent in checkmate; in self-driving cars, its goal is to get from A to B without crashing. AI can also be used in the financial sector, where it can alert fraud departments to unusual spending patterns on a bank card or large amounts of money being deposited in bank accounts.

Another example of AI is in the field of robotics where basic expert systems are incorporated. These tend to use forward chaining where there is a clearly defined goal, such as moving from one spot to another, although the variables and obstacles may be numerous. Natural language processing (NLP) is another application of AI. The goal is for people to be able to converse with computers and computers being able to understand. Such systems tend to use a mixture of forward and backward chaining.